University of California, Berkeley
Physics 110A Fall 2001   Section 1 (*Strovink*)

Problem Set 2

1. Griffiths 2.18

2. Griffiths 2.20

3. Griffiths 2.25 (c) only

4. Griffiths 2.32 (a) and (b) only

5. Griffiths 2.36 (a), (b), and (c) only

6. Griffiths 2.39

7. Griffiths 2.50

8. According to the Proca equations (a relativistically invariant linear generalization of Maxwell's equations accommodating the possibility of a finite rest mass m_0 for the photon), Gauss's law is modified to become

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\epsilon_0} - \frac{\phi}{\bar{\lambda}^2} \, ,$$

where ϕ is the electrostatic potential and

$$\bar{\lambda} \equiv \frac{\hbar}{m_0 c}$$

is the reduced (by 2π) Compton wavelength of the photon.

Following Williams, Faller, and Hill, *Phys. Rev. Lett.* **26**, 721 (1971), consider two concentric spherical perfectly conducting shells of radii R_1 and R_2, respectively, with $R_2 > R_1$. Imagine that the inner sphere is isolated and that the outer shell is driven by an RF oscillator so that it has a potential (relative to ∞)

$$\phi_2(t) = V_0 \cos \omega t \, .$$

In the modified form of Gauss's law, make the following approximation for the value of ϕ which appears in the last term; this is a valid approach because the factor $\bar{\lambda}^{-2}$ multiplying it is very small. The approximation is to set $\phi = \phi_2$ everywhere within the outer sphere. Construct a Gaussian surface consisting of a third sphere at radius r, where $R_1 < r < R_2$. Consider the volume integral of

$$\nabla \cdot \mathbf{E} - \frac{\rho}{\epsilon_0} + \frac{\phi}{\bar{\lambda}^2}$$

within that surface. Using the divergence theorem, convert it to a surface integral over the Gaussian surface. Evaluate the integral to obtain the (radial) electric field at r. Your result should contain a term proportional to the charge q on the inner sphere, and another small term proportional to m_0^2. Integrate this electric field from R_1 to R_2 to solve for the potential difference v that would be measured between the inner and outer spheres.

Assuming that $q = 0$, $R_1 = 0.5$ m, and $R_2 = 1.5$ m, and that V_0 is 10 kV, find the voltage v between the inner and outer spheres that would be observed if the photon had a rest mass $m_0 = 10^{-15}$ eV$/c^2$.